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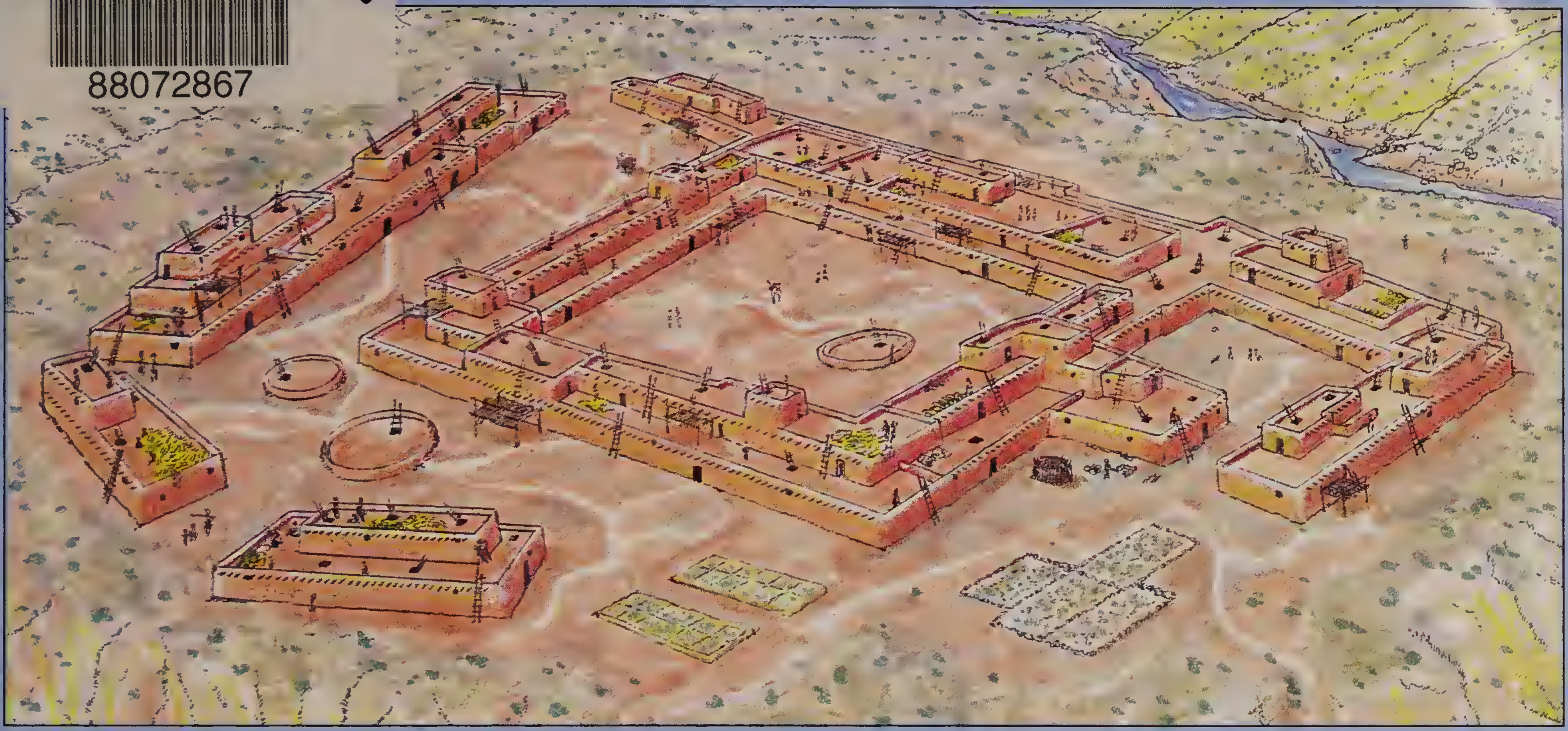

ENVIRONMENTAL TECHNOLOGY IS AN ANCIENT SCIENCE

THE HUPOBI HERITAGE PROJECT

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By Linda Lippitt, Terrill L. Nickerson,
Doreen Bailey, and Stephen L. Fosberg

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How can one express the social complexity and vitality of a town that no longer exists? Today, only about 500 people live along the Rio Ojo Caliente in northern New Mexico. Five hundred years ago, five Tewa villages sustained a population of 5,000 to 10,000 through a thriving agricultural technology. A cursory look at the area now reveals little, since the adobe homes of the once-thriving communities have long since weathered down to low mounds.

Yet children can still discover evidence of the ingenuity of these ancient peoples in adapting to the dry climate of the pinyon-juniper lands. Their terraced gardens covered with gravel mulch suggest practical approaches to living with nature harmoniously in an area of little water and sandy soils. As we become increasingly aware of the environmental effects of more recent technologies, we should consider carefully these ancient methods.

(Above) Artist's reconstruction of Hupobi Pueblo, *circa* 1400.

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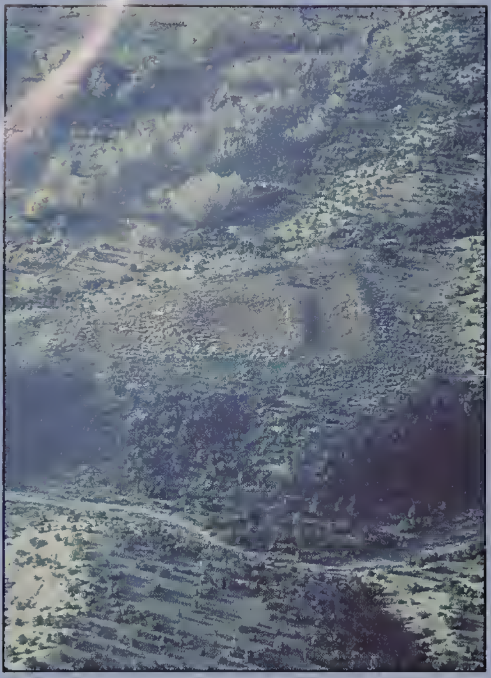

BLM, Taos (N. Mex.) Resource Area

Aerial view of Hupobi as it looks today.

ABOUT HUPOBI

Hupobi is one of 17 extensive ruins in the Chama region of northern New Mexico. Its 10 eroded blocks of 900 ground-floor rooms and another 300 second-floor rooms are distributed around three open plazas. The site was occupied from the mid-1300s to the mid-1500s. Hupobi's prehistoric dwellers practiced dry-farming agriculture to meet the challenges of the hot, arid environment. The exact cause for abandonment of the site remains a subject of much debate.

The ancient inhabitants of Hupobi handed down to the modern Tewa Pueblos of northern New Mexico a rich cultural heritage. Today, more than 30,000 tribal members in 19 pueblos across the state speak their traditional languages of Keres, Tewa, Tiwa, Towa, or Zuni, as well as English. They live and work in their home villages and in the cities of Albuquerque, Santa Fe, and Los Alamos. Their children keep alive the culture of a resilient agricultural people who lived in settled communities centuries before the arrival of the Spanish explorers.

At the Santa Fe Indian School in Santa Fe, New Mexico, staff and students collaborated with the New Mexico Bureau of Land Management to develop a cooperative educational project focusing on the agricultural and architectural technologies of the Hupobi Pueblo some 500 years ago. The group created a multimedia computer exhibit for display in the Gateway to the Past Museum outside of Abiquiu, New Mexico.

Students with direct ancestral ties to the people of ancient Hupobi conducted the research and interpreted their findings. The exhibit they set up informs visitors of the permanence, beauty, and technical skills of their living heritage. Subsequently, teachers at the school wrote a culturally relevant science curriculum focusing on dry-farming agriculture. Four activities from the curriculum are featured on the accompanying foldout, following page 24.

As students explore the natural methods carefully selected over centuries by the Hupobi people, they learn about ways to farm without harming the environment, without relying on fossil-fuel-driven machinery, and without rerouting natural resources across great distances. These lessons give students a new perspective on finding solutions to current problems. How can today's agricultural sector better use limited water supplies? Is it possible to adapt ancient techniques to help conserve this still-precious resource?

IN TOUCH WITH NATURE

The deserts and high mesa areas of the Southwest presented several challenges to prehistoric inhabitants. Given the difficulty of their environment, these peoples adapted quite well. In building their homes and growing their crops, they showed a keen understanding of how to work in harmony with the natural world.

In the beginning, they experimented with various techniques in their quest to survive. One of the more successful was a method called *dry-farming agriculture.*

Most of the Southwest, with the exception of the high mountain areas, is hot and arid, receiving little rainfall. The area is also characterized by large expanses of flat, unprotected valley plains containing very poor soil. Small mountain ranges occasionally interrupt the valleys. These mountain ranges usually encompass narrow canyons that do not contain enough space for planting large fields.

The success of a growing season depends not only on rainfall, but also on how much of that rainfall percolates through the ground to the roots. Penetration of the water below the surface is known as *infiltration.* The *infiltration rate* describes the amount of moisture that sinks into the soil within a given time period.

Soils in the Southwest generally consist of loose sands and gravels, called *alluviums*, that do not trap or retain water well. These alluvial soils tend to be very shallow. Although a "shallow" soil sounds as though it would let more water reach plant roots, this is not the case in desert soils.

The Rio Grande Valley usually receives two major periods of precipitation. The spring rains of April and May are characterized by slow, drizzling rain that allows for good infiltration. Although spring rains bring necessary moisture to the seeds, they are less important than those that arrive in late summer. These rains bring moisture in the hottest part of the season, when it is most needed.

They arrive in torrential downpours that dump tremendous volumes of rain in a very short span of time. This pattern makes infiltration difficult.

Alluvial soils are very porous, with many air spaces between the grains of sand or gravel. Despite this, when the rain comes down rapidly, these spaces fill up and no more water can infiltrate the ground. The excess runs off on the surface and washes away. This is why *arroyos* (streams that remain dry except during the rainy season) fill up and flood so frequently in late summer.

DRY FARMING

The early inhabitants of Hupobi developed special farming methods to increase the amount of land that could be planted and to decrease the amount of soil lost with each rain. *Check dams,* along with other flood control mechanisms, helped stop the erosion of thin topsoil. Hupobi farmers would place a small line of rocks across the path of the channels where runoff typically flowed. This interruption in the flow allowed soil that had been picked up by the water to resettle and be deposited behind the rock line. As the waterflow slowed, it lost its ability to carry sediment. This created new plots of soil to be planted, and it protected areas farther downstream. At the village of Hupobi, the ancient inhabitants set up check dams on all the terraces that paralleled the nearby river.

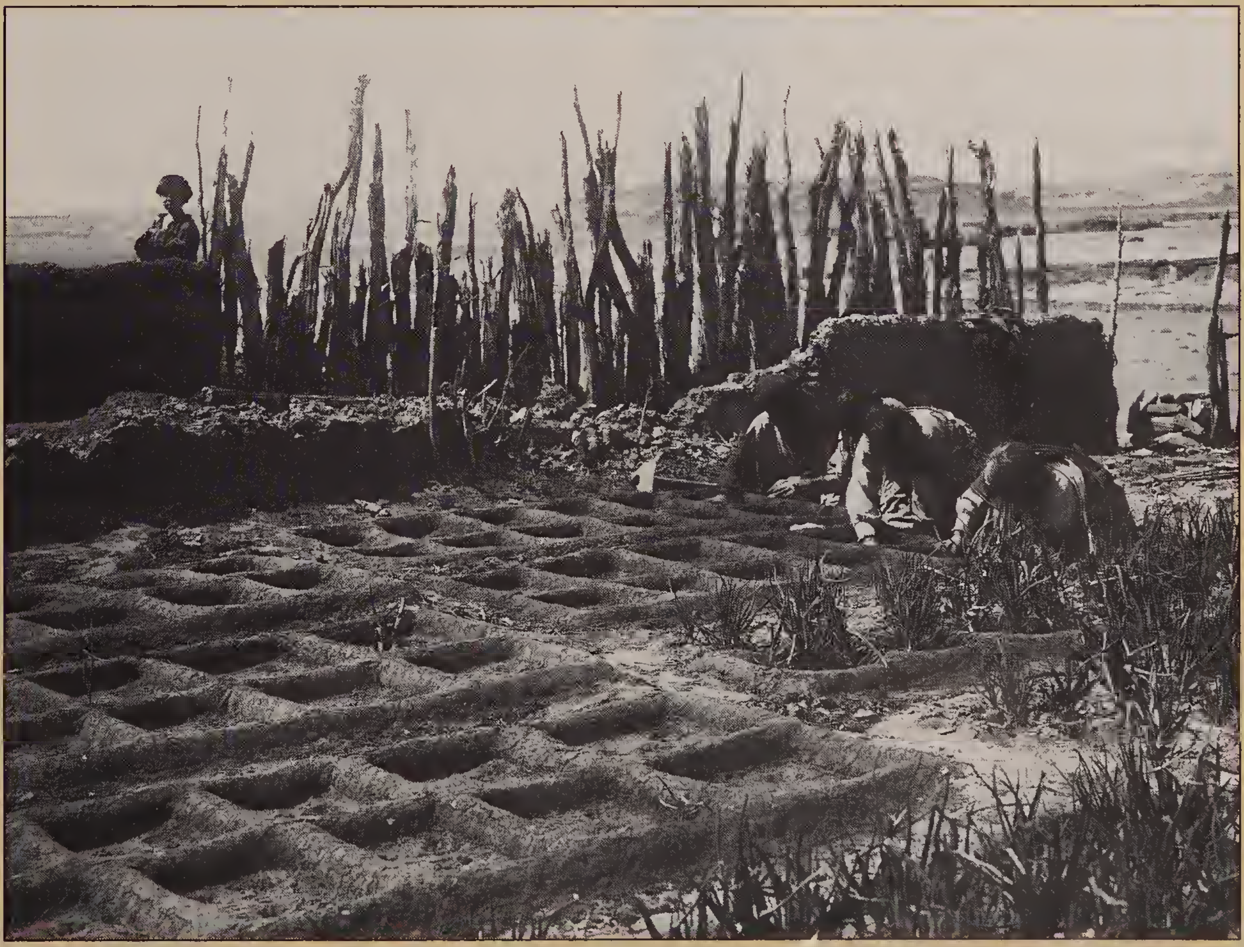
Another technique common throughout the Southwest involved placing rock borders around individual agricultural plots. These *grid gardens* served both to identify plots and to protect the soil from being carried off with each rainstorm. On some prehistoric fields, a thin layer of gravel or small stones would have been spread over the area. This *gravel mulching* provided one more method of slowing down the runoff and protecting the soil from erosion. It also slowed water evaporation, insulated plots from frosts, and reflected heat during the hottest part of the summer. Thus, a dry farm plot would be more likely to yield a crop, and the people of Hupobi could harvest maize, beans, and squash in the fall.

The *waffle garden,* another dry-farming technique, was a square plot, anywhere from one to four meters per side, surrounded by a clay or adobe wall that rose 30–50 cm above the ground. The overall pattern resembled a giant breakfast waffle. The waffle plot may have had a gravel mulch as well. Both methods served to hold the water in the soil longer, to retard evaporation, and to

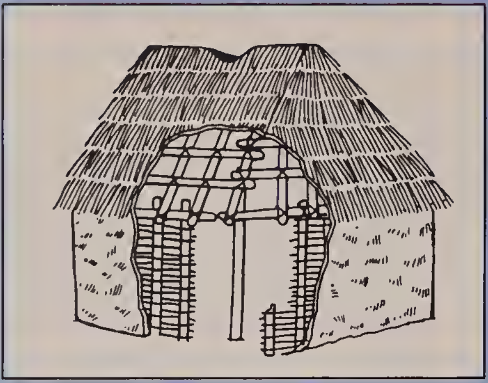
Stephen L. Fosberg

The remains of an ancient Hupobi grid garden.

The Zuni people developed this waffle-garden design, which is still used today as an ecological method of conserving water.

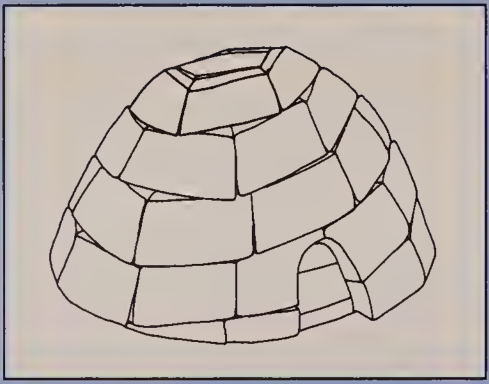

Courtesy of the Museum of New Mexico, negative #8742. Photograph by Jesse Nusbaum, 1911

Housing Adapted to Other Environments

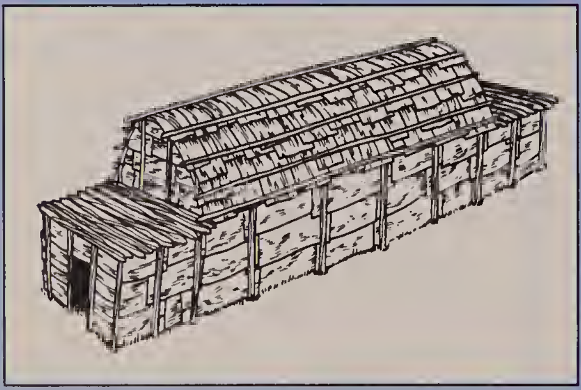


Moundbuilders of the Southeast made hills on which to establish their homes. They lashed canes to a frame of hickory poles, and then plastered adobe stiffened with Spanish moss over the canes. The roofs were thatched with grass.

Tribes of the Great Plains lived on horseback, with their tepees trailing behind them. Tanned buffalo hides provided covering for the tepees.



Constructed of snow blocks and insulated with hanging furs, the igloo could be a simple shell for one person or a cluster of bubbles linked by inner passageways for many families.



The Iroquois felled trees from forests of the Northeast. A structural frame of saplings was covered with bark sheets or sewn reed mats. The communal "long house" was often more than 30 meters long.

increase chances for crop success. Waffle-garden agriculture has been practiced and documented historically at Zuni Pueblo, in western New Mexico. It is likely that the inhabitants of Hupobi practiced it in addition to their grid gardens.

Crop success also depends on whether the slope containing the field faces northward or southward. Slope direction, or *aspect*, dictates how long it takes for winter snows to melt and how many hours of daily sunlight the area receives. Ultimately, aspect determines the length of the growing season.

The daily maximum temperature of the soil also differs significantly between a north- and south-facing slope—as much as 10 C°. That difference has a significant effect on young seedlings that depend on the soil for heat until they break through to the surface.

This information was not lost on the inhabitants of the Hupobi, who made careful observations of the natural world. Because maize requires at least 120 frost-free days to grow, farmers almost always chose to plant it on the south-facing slopes that would provide additional daylight and a longer growing season.

Classroom Agriculture

In addition to the activities described on the accompanying foldout, try the following exercises for further study.

✷ Compose a photographic essay documenting local agricultural concerns, such as soil condition, erosion, or irrigation needs. Choose one of these concerns to research and then present possible approaches to alleviate or correct the problem.

✷ Invite an agent from the county's agricultural extension department and interview her about the importance of agriculture to the local economy.

✷ Find the agricultural zone for your area. Determine the average number of frost-free days and the average amount of rainfall for this zone. With a seed catalog, develop a chart that displays the types of vegetables and flowers that would grow well in that climate. Which of these would be affected by a 10 percent decrease in rainfall? What plants would grow well if adaptive technologies, such as protective breaks, mulches, or irrigation, were put into action?

✷ Borrow a soil-testing kit and pH meter from a local greenhouse. Take soil samples from the school grounds or students' homes, analyze them, and graph the results. If students were to grow a garden, what would be necessary to prepare the soil?

✷ If space permits, have students plant a small garden to take advantage of their research. Try growing some of the seed varieties of corn, squash, and beans traditionally planted by Native Americans.

At Home with Nature

The technologies and architectural practices each culture develops depends upon their environment and the physical and social needs of the group.

At Hupobi, the residents chose to gather together in multilevel homes built in an apartment-like fashion. Adobe dwellings with stone foundations surrounded a central rectangular courtyard. The people also built round, underground ceremonial rooms called *kivas*, additional storage rooms, and public areas. They developed adjacent agricultural fields and erected pens for domesticated turkeys. The early Spanish explorers named such settlements *pueblos,* the Spanish term for *towns.*

The buildings were made of *coursed* or *puddled* adobe rather than adobe bricks. This soft, mudlike plaster was layered over a foundation of stones in courses (applications) to the desired height. The resulting structure was strong enough to allow for two and even three stories. Outside ladders were used for entry into the upper levels.

Long logs of peeled pine, called *vigas,* supported the roof. Shorter lengths of cedar branches were layered over the logs. These *latillas* supported a yucca or grass mat, which became the roof. A thick layer of mud offered further protection from rain and insulation from heat and cold. Wooden gutters, or *canales,* drained water from the flat roofs during heavy rains. The rooms were painted with a white plaster and the floors were of hard, packed soil.

These architectural details reflect the materials at hand in the surrounding environment. The mountain areas provided tall trees for vigas, and the people could harvest the cedar branches and other vegetation nearby. River water and the composition of the site's soil allowed the people to build with adobe, which absorbs the sun's heat, keeping rooms cool during the day; during winter's cold nights, adobe gives off heat, keeping rooms warm.

As a settled agricultural community, the people could securely store their harvests and their tools within their dwellings. Clustered within a settlement, they pooled their talents to help one another.

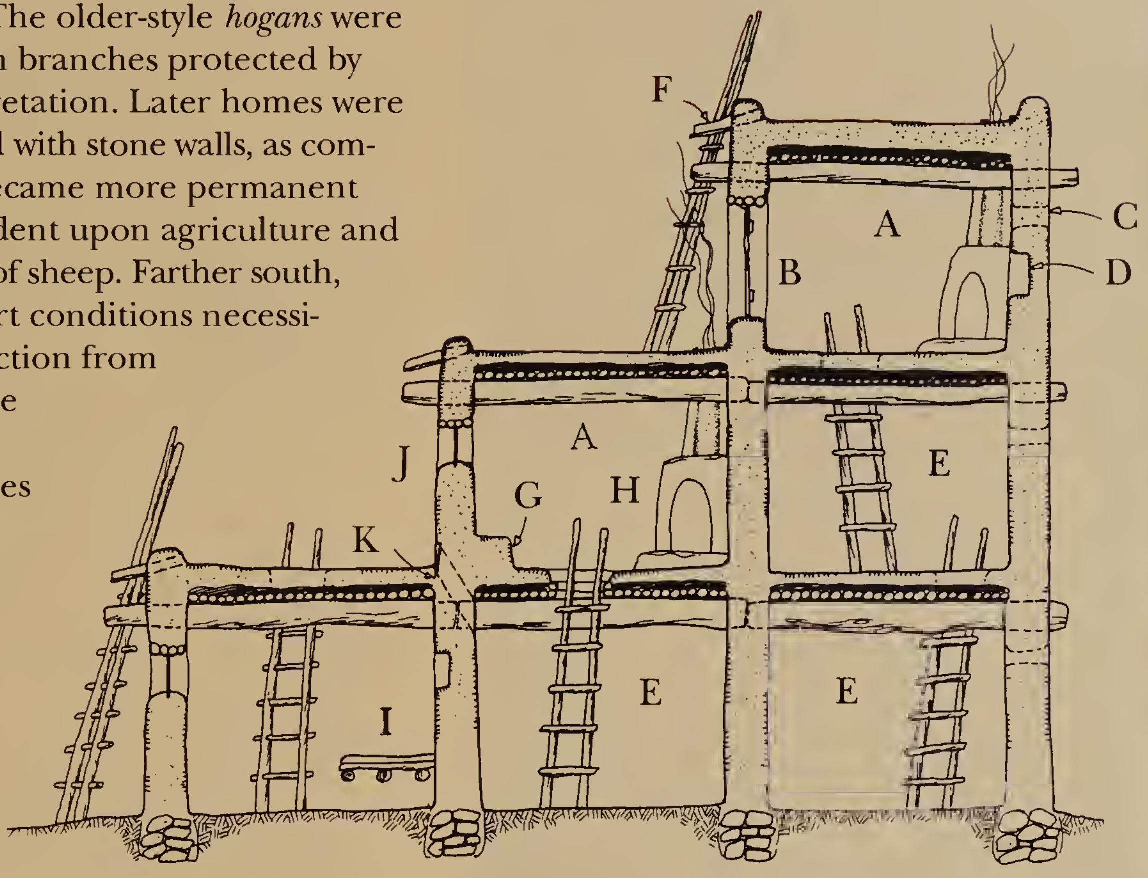
Other Native American communities in the Southwest also adapted their lifestyles, including architecture, to their environment. In Mesa Verde, Colorado, visitors today can explore the homes of other Pueblo tribes that are based on cliff dwellings. These homes were built into cliffs protected by rock overhangs, often facing south to be warmed by the sun, and featured many of the architectural details that the people of the Hupobi also developed a few centuries later.

The traditional Navajos built round dwellings covered with mud or dirt roofs. The older-style *hogans* were framed with branches protected by skins or vegetation. Later homes were constructed with stone walls, as communities became more permanent and dependent upon agriculture and the raising of sheep. Farther south, where desert conditions necessitated protection from the heat, the Pima and Papago tribes of Arizona developed a *wattle and daub* construction. They made the foundation with brushy vegetation or reeds covered with mud. The Yaqui people built *ramadas,* open-sided roofed structures that let in cooling breezes.

Beyond the basic sizes and shapes of these traditional dwellings, the climate and materials of each environment influenced the decoration and furnishings of the homes. The food and styles of food preparation and storage were also dependent upon the environment. But contact with other groups and the technical advances of each generation changed how people viewed what was a necessity for their lifestyle.

Contemporary Pueblo tribes continue to take pride in their ancestral homes. Taos Pueblo, north of Hupobi, is one of the oldest continuously inhabited villages in North America.

CROSS SECTION OF AN IDEALIZED PUEBLO



Rising solar heat warms south-facing rooftops, creating outdoor work areas during the winter months.

A. Sleeping/Cooking Room
B. Door
C. Air Vent
D. Niche
E. Store Room
F. Canale
G. Banco
H. Fireplace
I. Sleeping Room
J. Small Window
K. Angled Window

Courtesy of Santa Fe Indian School

In our modern, multicultural classrooms, we must consider carefully the varying definitions of and approaches to "science" brought to the group by individual students. The learning styles, factual foundations, and home community approaches to scientific learning may differ dramatically. What textbooks declare to be a neutral and logical approach reflects a single westernized strategy. Activities such as the Hupobi project provide one arena for exploring alternative rationales and respectfully enhancing cross-cultural appreciations of the language, thought, and behaviors of all who are engaged in scientific inquiry.

Courtesy of Santa Fe Indian School

The modern descendants of the people of the Hupobi may live in individual homes furnished with all the modern conveniences, but the heart of the traditional pueblo remains the centuries-old community buildings constructed around a plaza and plastered annually with fresh adobe.

✱ Across what is now the United States, Native peoples developed styles of architecture that reflected their environments and their cultural values. Referring to library resources, have students explore the home-building styles of the peoples listed below and prepare an illustrated report addressing the following questions:

How did the climate affect peoples' need for shelter and the types of animals and plants that could be found in the area?
Was there a need for seasonal housing?
What were their major sources of food and water?
Did the people hunt or farm?
Did they require temporary portable shelter or more permanent structures?
Did the people live in isolated family groups or in communal areas?
Was it necessary to develop defensive fortifications for protection from raiders?
What happened to the homes when families expanded through marriage?

Groups of interest include the moundbuilder tribes of the Southeast, who built earthwork mounds; the Cahokia of southern Illinois, who built cities with palisades (wooden fortifications), plazas, markets, and ballcourts; Algonquins, who lived in wigwams; Ipiutak, who constructed igloos; Seminoles, who built pavilions in the Everglades; the Iroquois who built longhouses in the Northeast; and Plains tribes, such as the Sioux, Comanche, and Cheyenne, who developed the buffalo skin tepee.

✱ How does our architecture today reflect the way individual communities adapt to the environment? Have students research how homes are built in different regions of the country and then construct dioramas to illustrate various styles.

✱ Have students research modern home-building technologies that are energy-efficient. Ask them, What new materials are being developed to improve energy efficiency? What makes a solar home "active" or "passive"? What are the advantages and disadvantages of building a home partly underground?

✱ Invite a representative from a Native American group to speak about how contemporary Native Americans blend their traditional community practices with modern conveniences, demands, and personal desires.

WE HAVE A CHOICE

The development of environmental technology is a key adaptation of all successful communities. Living with the land to nurture all beings and to sustain its natural resources requires a thoughtful balance of respect for the Earth and for humanity's desires. In seeking to achieve this balance, we can look for examples established by peoples of long ago. The scientific insights that they cultivated through observation over generations can provide possible solutions to current problems. The indigenous inhabitants who live and practice agriculture in the Southwest today bear witness to the success of these earlier peoples. As modern agriculture expands into areas where water is not naturally plentiful, could we apply the ancient agricultural techniques of the Hupobi?

MODERN TECHNOLOGY EXPLORES ANCIENT LIFEWAYS

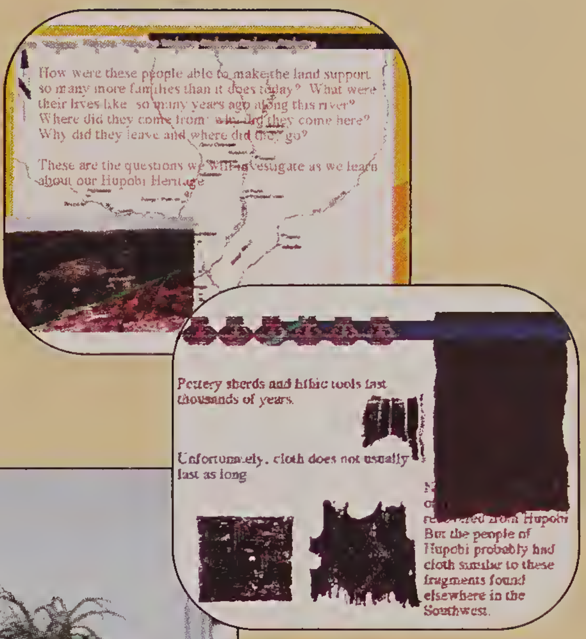
Students at the Santa Fe Indian School, a tribally governed secondary school for 570 Native American students from across the Southwest, receive a contemporary education while emphasizing the values and goals of their home communities. The five high school juniors who worked on the Hupobi Heritage Project are from San Juan and Santa Clara Pueblos, located north of Santa Fe. To represent fully the vitality of Hupobi Pueblo, they created a multimedia production that includes illustrations, animation, 3-D replications, video segments, and sound. A computer platform adds the interactive aspect, allowing the viewer to choose from an electronic menu of "chapters" on Hupobi agriculture, architecture, technology, trade, and history. The program challenges visitors to participate in the choices the Hupobi people made as they contended with the environment each day.

With modern technology, students could better document and explain their ancestral ways. They videotaped their elders, created movies for computer use, mastered the complexities of database and word-processing programs, and refined their English writing and speaking skills. The students' work on this project also gave them insights into the careers of photography, videography, history, archaeology, anthropology, museology, and resource management. More than 100,000 people per year visit the Ghost Ranch Museum complex; those visitors will be judging the interns' work in a real-life performance assessment.

Most importantly, students gained renewed respect for their cultural heritage, its technology, and its language.

✱ Select a historic site in your community that has not yet been interpreted for the public. Many of the sites listed on the National Register of Historic Places, although deemed significant, have not yet been interpreted. Request the list of cultural resources worthy of preservation from your state's historic preservation officer. As a class project, write an interpretive pamphlet for a site and illustrate it with historic photographs or original artwork by students. Work with local historians, residents, and government officials to research the history of the site. Link the project to science learning by investigating historic technologies used at the site. Ask for financial support from your school's PTA, the local chamber of commerce, local government, or your area's historical society. Distribute your completed pamphlet at public libraries, community centers, courthouses, tourist bureaus, and, if possible, at the site itself. This activity will hold even more meaning for students if the site selected for interpretation relates to their own cultural heritage.

A technical description of the Hupobi Heritage interactive display is available for readers who would like to know more about the computer technology involved in the project. To request a copy, please write to Doreen Bailey, Ventures in Technology, Santa Fe Indian School, P.O. Box 5340, Santa Fe, NM 87502.



How were these people able to make the land support so many more families than it does today? What were their lives like so many years ago along this river? Where did they come from? Why did they come here? Why did they leave and where did they go?

These are the questions we will investigate as we learn about our Hupobi Heritage

Pottery sherds and lithic tools last thousands of years.

Unfortunately, cloth does not usually last as long

recovered from Hupobi But the people of Hupobi probably had cloth similar to these fragments found elsewhere in the Southwest.

(Above) Screen displays from the interactive computer program, part of the multimedia exhibit at the Gateway to the Past Museum near Abiqui, New Mexico. (Left) These students and teachers from the Santa Fe Indian School created the computer program.

Courtesy of Santa Fe Indian School

The Hupobi Interns were:
Denise Atencio, San Juan and Laguna Pueblos;
Rosina Cata, San Juan Pueblo;
Melissa Chavez, San Juan Pueblo;
Charlene Kellywood, San Juan Pueblo;
and Charles Suzao, Santa Clara Pueblo.

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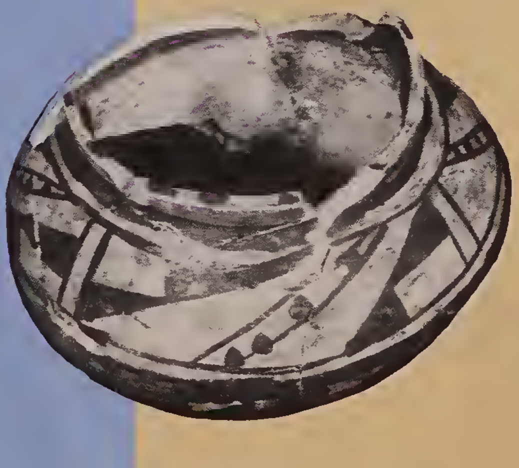

Courtesy of Santa Fe Indian School

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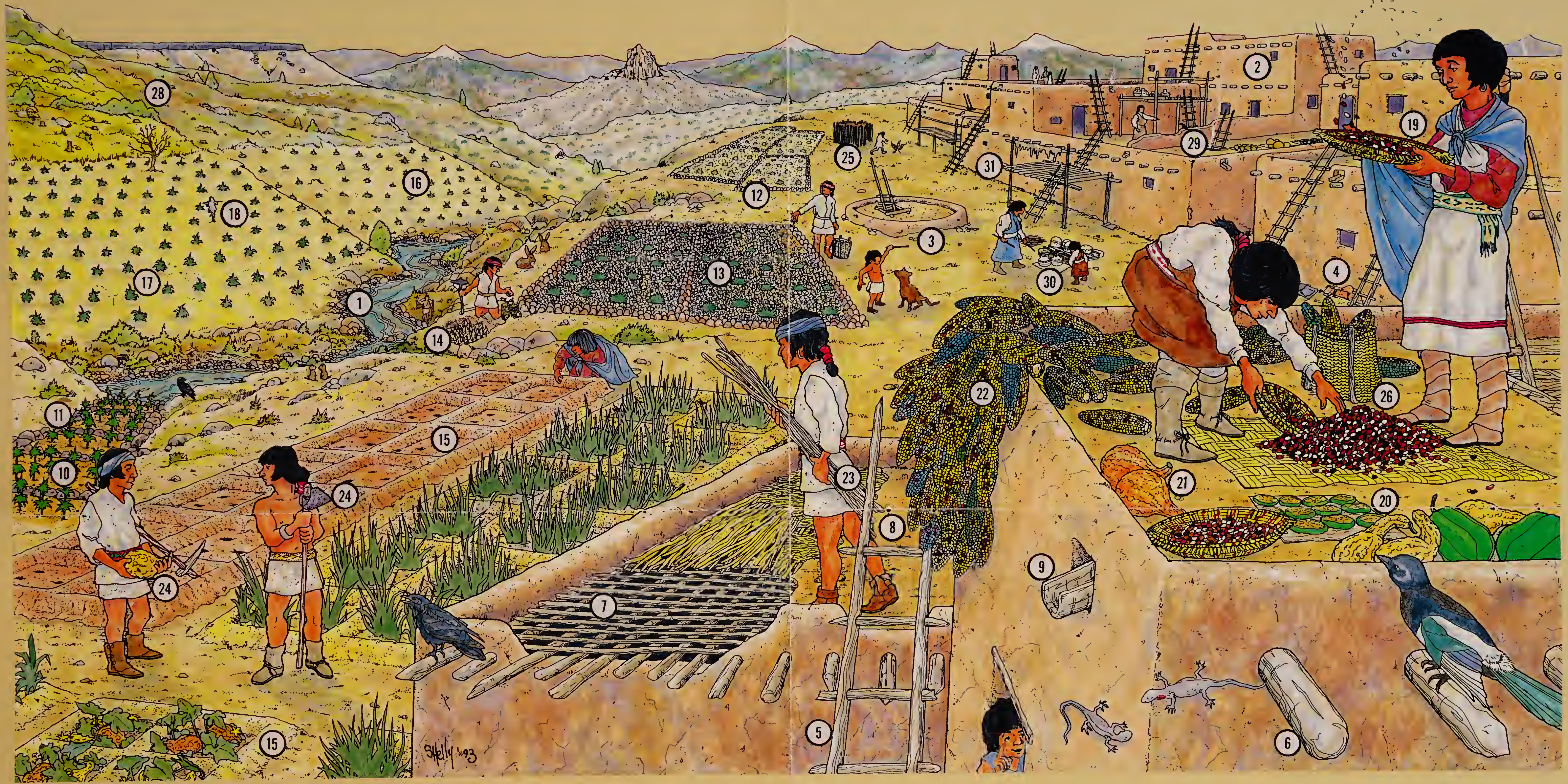
Illustrations and associated historical research by Shelly Fischman.

ADOBE AND MAIZE

AT HOME WITH NATURE AT HUPOBI PUEBLO



Artwork and associated historical research by Shelly Fischman

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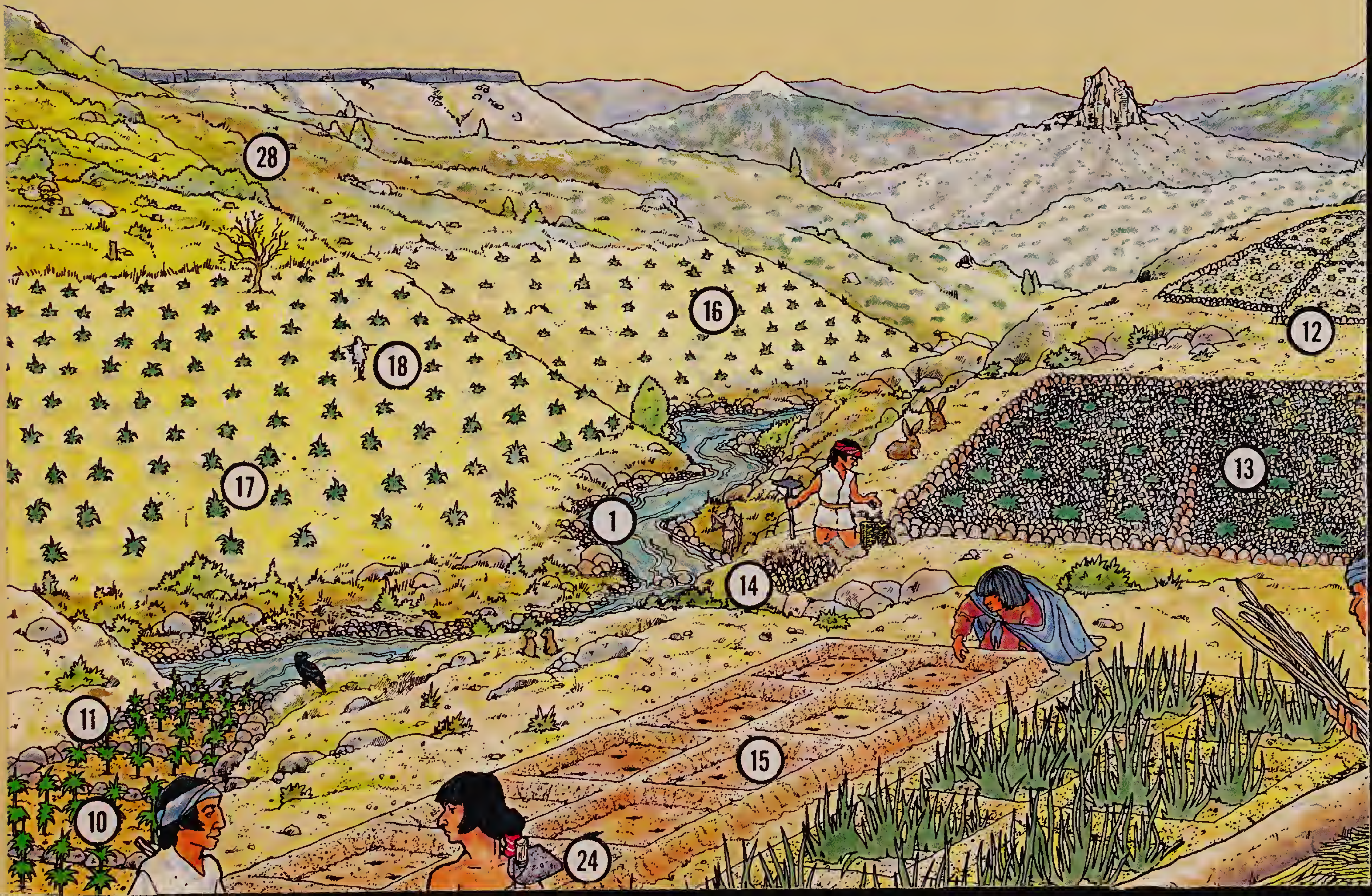
2. Pueblo style—multilevel homes built in apartment-like fashion
3. Kiva—round, underground ceremonial room
4. Coursed adobe—construction technique using layers of a mudlike plaster over stone
5. Outside ladder
6. Vigas—logs of peeled pine to support roof
7. Latillas—lengths of cedar branches covering vigas
8. Insulating layer of mud over a yucca or grass mat
9. Canale—wooden gutter to drain roof
10. Terrace gardens—use of steep hillsides for food production
11. Check dam—line of rocks to channel rainfall
12. Grid garden—rectangular or square agricultural plots bordered by rocks
13. Gravel mulch—thin layer of gravel or stones protecting soil surface
14. Gravel bed—source for stone mulch
15. Waffle garden—square plots bordered by a short clay or adobe wall to collect moisture
16. Planted slopes facing southward, receiving maximum sun
17. Maize—original species of corn domesticated by Native Americans
18. Scarecrow
19. Winnowing of bean seeds
20. Sun-drying vegetables
21. Squash for winter storage
22. Corn drying to grind for flour or to cook in posole, a dried corn stew
23. Roof repair
24. Tools—gourd water container and stone hoe
25. Turkey pen
26. Woven grass basket
27. Pottery for food storage
28. Pinyon-juniper zone
29. Flat roof used as additional living area
30. Pottery kiln
31. Shade ramada and drying rack

ADOBE AN

AT HOME WITH NATU



ND MAIZE

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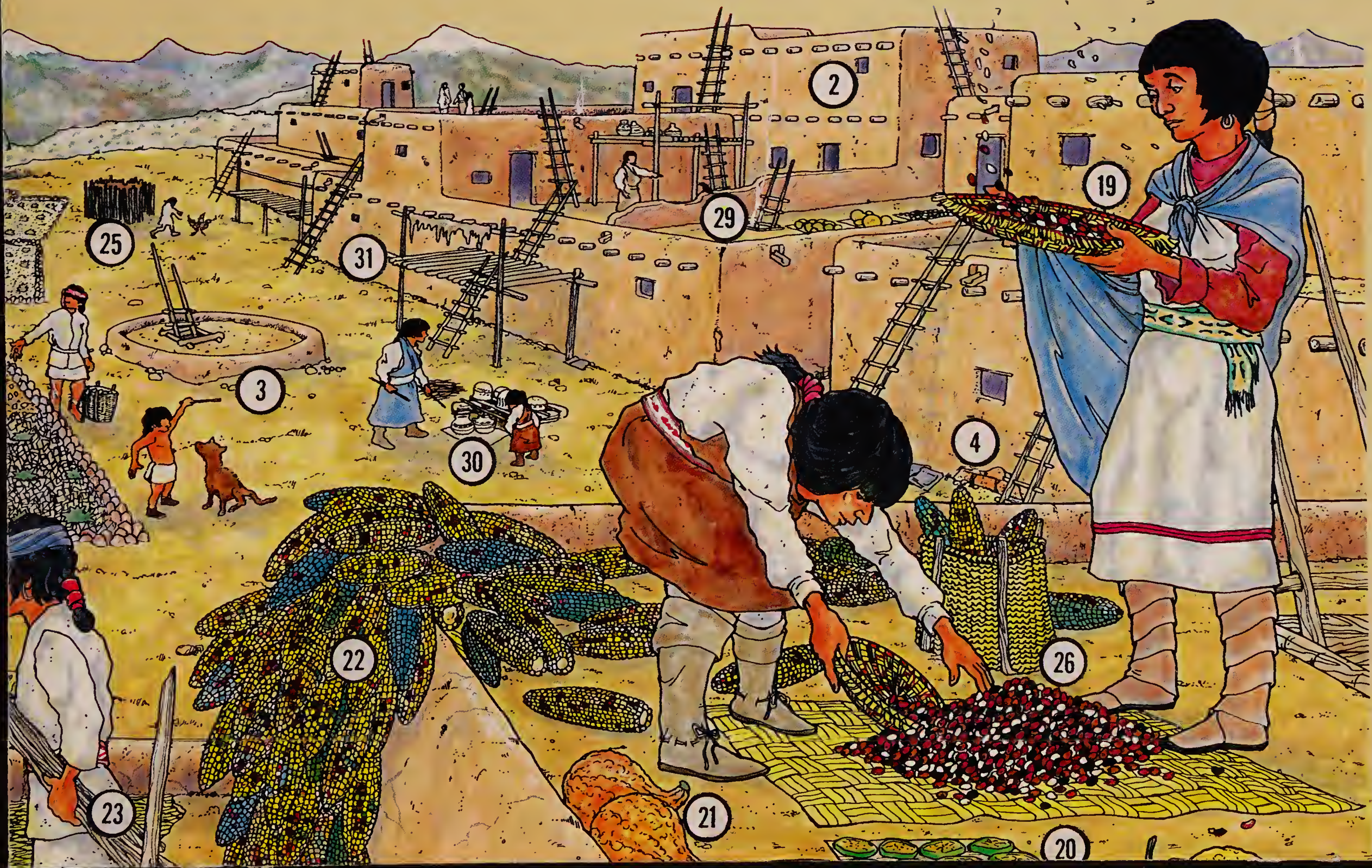

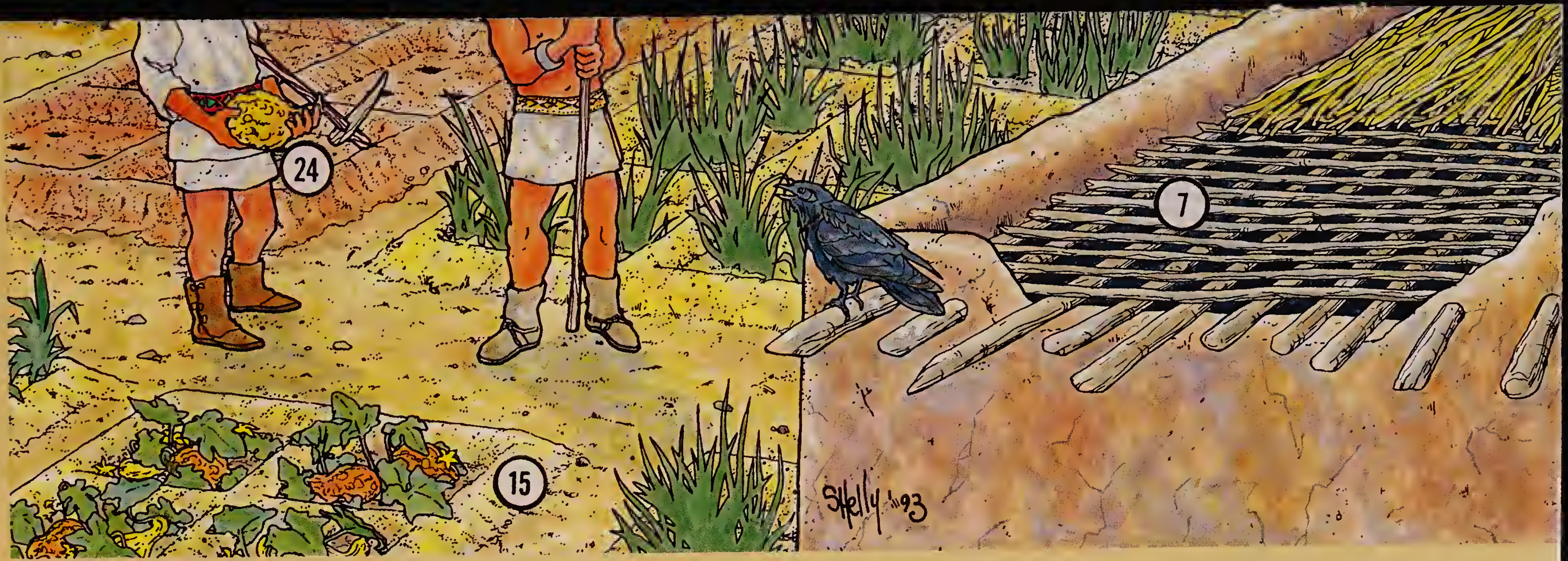

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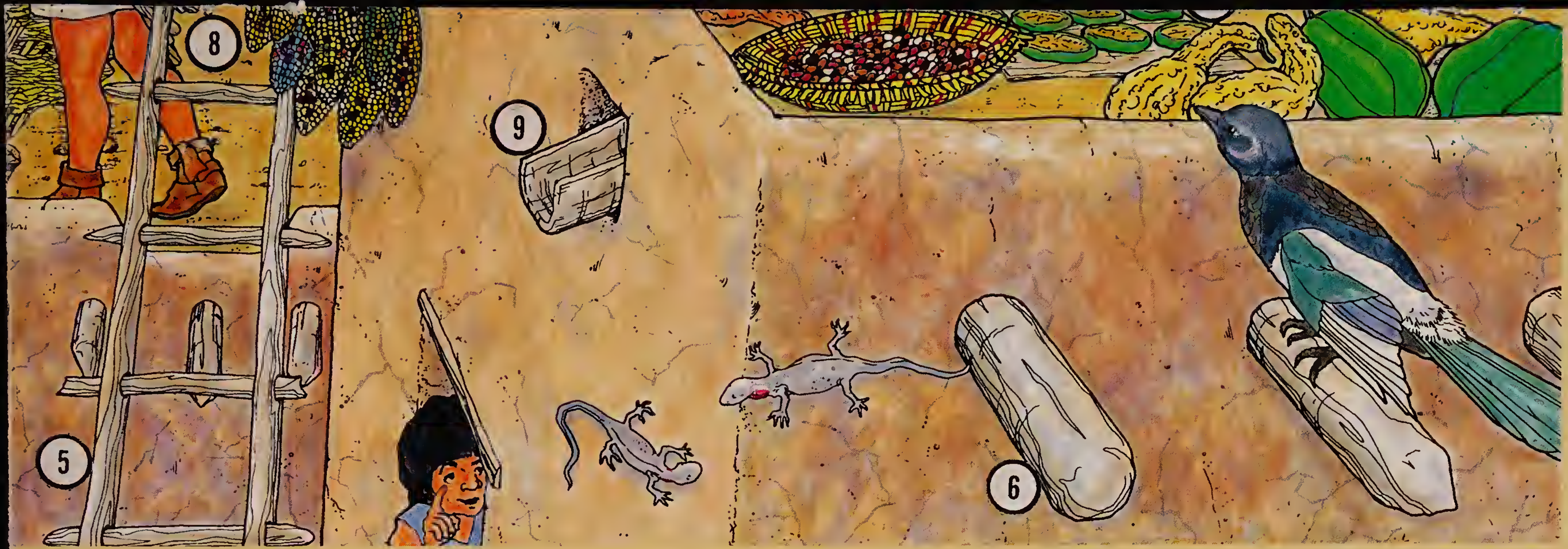

Artwork and associated historical research by Shelly Fischman

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16. Planted slopes facing southward, receiving maximum sun
17. Maize—original species of corn domesticated by Native Americans
18. Scarecrow
19. Winnowing of bean seeds
20. Sun-drying vegetables
21. Squash for winter storage
22. Corn drying to grind for flour or to cook in posole, a dried corn stew
23. Roof repair
24. Tools—gourd water container and stone hoe
25. Turkey pen
26. Woven grass basket
27. Pottery for food storage
28. Pinyon-juniper zone
29. Flat roof used as additional living area
30. Pottery kiln
31. Shade ramada and drying rack

EXPLORING ANCIENT WATER WAYS

Technology is applied science. When people use their personal observations and experiments to develop practical solutions, their ideas and tools become part of the technological resources to be shared with others. The farmers at Hupobi had a great deal of experience growing food in an area of little rainfall. Consequently, they developed dry-farming technology that worked for their environment.

The activities described below let students gain a personal experiential base to test the ancient technologies. Encourage them to ponder why these methods worked for the people of Hupobi, and how they would fare in their own environment.

You might also explore broader questions. For example, to what extent can people take technology developed in one environment and apply it, unchanged, to a second environment? Can scientists from one part of the world develop solutions for people living in other parts of the world? What can we learn from traditional peoples such as the Native Americans of the Southwest or tribal peoples of the South American rainforest?

WATER DIVERSION

Objective: Students will observe the effect of erosion on soil samples, demonstrate the effect of water diversion features on runoff as a way to control erosion and as a way to collect and retain soil, and simulate agricultural dry-farming techniques.

Materials: For this activity, you will need
- a large plastic tray (such as a kitty litter box);
- soil and gravel;
- a wooden block to support the tray;
- water;
- pebbles, small stones, or popsicle sticks;
- a 500-ml beaker;
- and a plastic drop cloth.

Procedure: Take the plastic tray and fill it with soil to within one centimeter of the top. Lightly pack the soil.

Pour about 500 ml water into the beaker, then place the tray on top of the plastic drop cloth. Tilt the tray about 20 degrees, supporting it on the wooden block. Gently pour the water from the beaker onto the middle area of the soil. Do not let the water flow too rapidly. Observe the pattern that the water makes as it runs down through the soil.

Now, repack the soil and refill the beaker with water. Place a thin layer of gravel over the top of the soil. Repeat the procedure. Observe and record. Take the small stones or popsicle sticks and place them across the path of the channel that was cut into the soil by the water. Make sure that the stones or sticks are securely in place. Again, pour the water onto the soil, observe, and describe.

Try doing this experiment while tilting the tray at various angles. You might also use a gardener's watering can with a sieve-style head rather than a beaker. This more closely simulates a rainfall and spreads the water over a greater area. The gravel mulch will significantly slow down the visible surface erosion, and the rock alignments, or check dams, will further slow erosion and serve as a means of soil catchment.

Ask students to draw or describe the erosion patterns witnessed in each step of the activity. How might the practices of rock alignments and gravel mulching have affected the people of Hupobi? (At the village of Hupobi, the ancient inhabitants used check dams and gravel mulches to control runoff, protecting the soil from erosion and slowing evaporation. These techniques increased the amount of land that could be planted and resulted in a greater abundance of crops.)

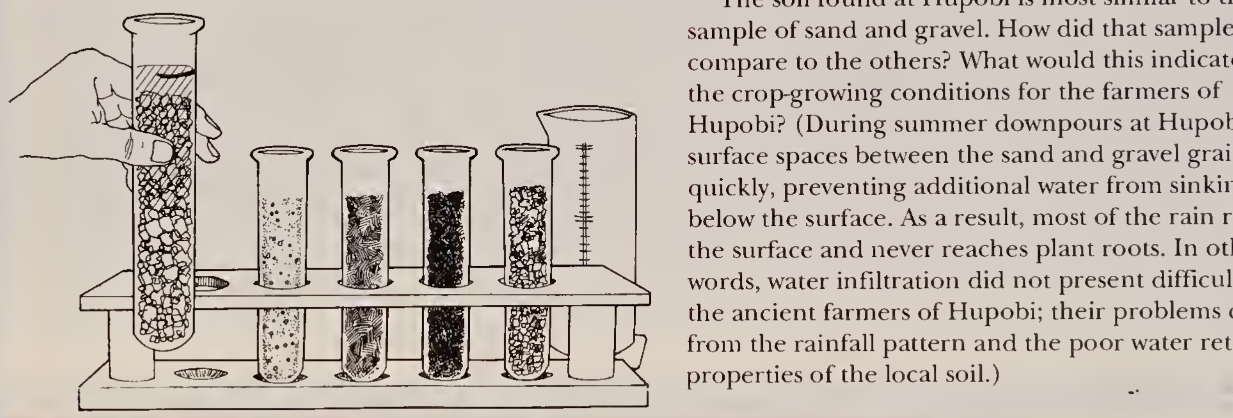
INFILTRATION RATES

Objective: Students will observe and compare the relative rate and depth of soil infiltration in five soil samples.

Materials: For this activity, you will need
- five large test tubes;
- a 50-ml graduated cylinder;
- sand, gravel, and clay;
- loam or potting soil;
- a sample of schoolyard or neighborhood soil;
- water;
- a metric rule;
- graph paper and grease pencils;
- and a test-tube rack.

Procedure: Begin by filling one of the test tubes ¾ full with sand. Give the test tube a little shake to settle the sand, but don't pack it. With the grease pencil, mark the test tube at the top of the sand and place it in the rack. Prepare the other soil types in the same manner.

Fill the graduated cylinder with 30 ml water. Note the time, and then begin slowly pouring the water into the top of the first test tube. Allow a small amount to soak in at first, then continue pouring until all the water is in the tube. Repeat the process with the remaining test tubes, pouring 30 ml water into each and noting the time you begin pouring.



Observe the test tubes carefully. When it becomes apparent that water in a particular tube is no longer filtering downward, record the time once more.

After infiltration has stopped in all the samples, mark the level to which the water descended. Then, measure the distance between the two markings for each sample. Compile your data on a chart.

Soil Type	**Time of Infiltration** (in seconds)	**Depth of Infiltration** (in centimeters)
Sand		
Clay		
Loam		
Sand and Gravel		
Local Soil		

The soils with the most visible space between grains should infiltrate the deepest and the fastest. The clay should show the least infiltration.

Ask the children to answer the following questions: Which soil allowed the water to infiltrate the fastest? (The sand and gravel sample should infiltrate most rapidly.) Which sample showed the deepest infiltration? How does your local soil compare to the other types?

The soil found at Hupobi is most similar to the sample of sand and gravel. How did that sample compare to the others? What would this indicate about the crop-growing conditions for the farmers of Hupobi? (During summer downpours at Hupobi, the surface spaces between the sand and gravel grains fill quickly, preventing additional water from sinking below the surface. As a result, most of the rain runs off the surface and never reaches plant roots. In other words, water infiltration did not present difficulties for the ancient farmers of Hupobi; their problems came from the rainfall pattern and the poor water retention properties of the local soil.)

WATER RETENTION

Objective: Students will demonstrate gravel mulching and build a model of a waffle garden to observe ways in which altering the soil can affect the amount of moisture the soil retains.

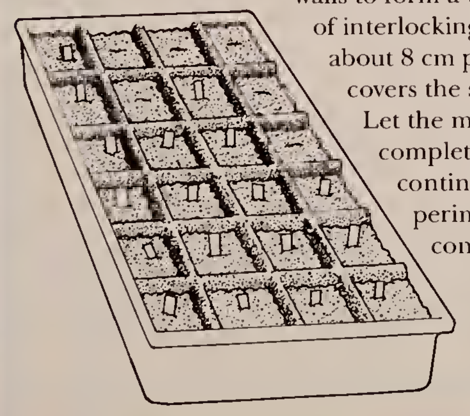
Materials: For this activity, you will need
- three plastic laboratory trays (45 cm x 60 cm, 5 cm deep) or soda-pop flats lined in plastic;
- soil, clay, and gravel;
- construction paper;
- a 500-ml beaker;
- a plastic bucket;
- water;
- and scissors.

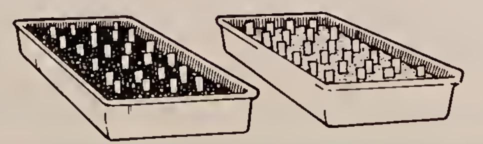
Procedure: Fill the three trays with soil to within 2.5 cm of the top. Pack the soil a bit, but don't overdo it.

Leave one tray as it is, containing just the soil.

For the second tray, evenly spread a thin layer of gravel over the soil.

The remaining tray will represent a waffle plot. Make it by filling the bucket halfway with soil and adding enough water to moisten it—until the soil is tacky, but not runny. With a handful of the moist soil, form a wall on the surface of the soil in the tray. The wall should be about 5–8 cm tall, 10 cm long, and 1 cm thick. Continue making mud walls to form a waffle pattern of interlocking squares, about 8 cm per side, that covers the soil surface. Let the mud walls dry completely before continuing the experiment. Cut the construction paper into 1 x 7-cm strips. Then, in the first tray, make a hole in the soil that extends to the bottom of the tray. Continue making holes, spacing them about 10 cm apart, until the entire surface has been punctured. Insert the construction-paper strips, one per hole, securely packing the soil around them. Repeat the process for the other two trays, making one hole per square in the waffle-garden model.





Next, fill the beaker with water and gently pour it over the surface of the first tray. Cover the entire surface evenly, and try not to pour water directly onto any of the construction-paper strips. Repeat with the other two trays.

Every hour, pull one of the paper strips from each of the trays, taking care not to tear it. Measure the part of the strip that is still moist. Continue to pull strips and measure them until they are gone or the soil has dried completely. Record the time that each strip is pulled, which tray it comes from, and how much of it is moist.

The data will show that the waffle-garden model retains moisture the longest, followed by the gravel mulch–covered soil. The uncovered surface is the least efficient at water retention.

Discuss the following questions: How do the three models differ? Why does the waffle garden work so well? How could the waffle garden be improved? (A gravel mulch would further increase the efficiency of the waffle garden.) What specific materials would the inhabitants of Hupobi need in order to make waffle gardens? (They needed clay and water to build the low walls surrounding the plots.)

You could try conducting this experiment on a realistic scale, if you have enough space on the school grounds. Or you can try the exercise with live plants over a long period of time, testing for productivity as well as water retention.

SLOPE ASPECT AND SOIL TEMPERATURE

Objective: Students will determine the effect of aspect (the direction faced by the slopes that contain crops) on soil temperature.

Materials: For this activity, you will need
- two empty half-gallon milk cartons,
- two laboratory thermometers,
- enough soil to fill both cartons,
- dark-colored construction paper,
- scissors,
- and graph paper.

Procedure: To construct the model, first cut away a side from one of the milk cartons, and staple or tape closed the top portion where the carton opens. Then, cut a rectangle of construction paper that measures the length of the carton and twice its width. Place the paper rectangle inside the carton so that half of it still extends above the side. Fill the carton with soil, which will hold the paper in place. Prepare the second carton in the same manner.

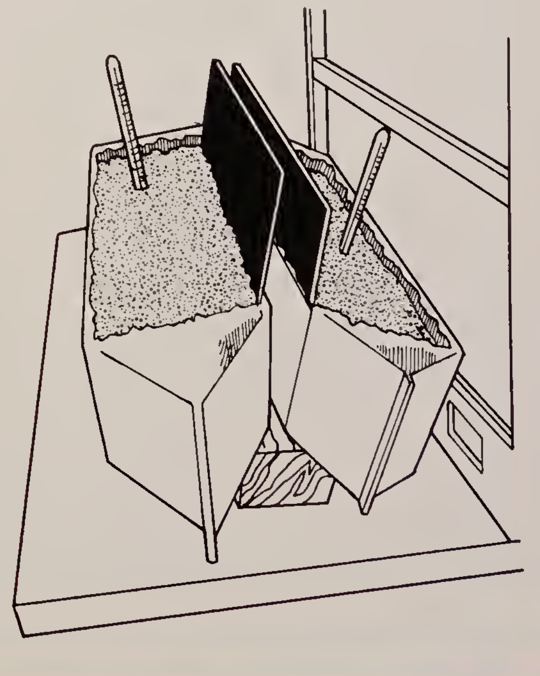
Find a window sill on which the two samples will fit with room to spare. They must also be easily accessible to students. Face one carton directly toward the outside, tilting it slightly to simulate a south-facing slope. The construction paper should be opposite to the side facing the window. Place the other carton in the window so that it faces away from the outside (construction paper toward the window), simulating a north-facing slope. Tilt the carton a bit.

Locate the center of each carton and push the thermometers into the soil about 5 cm. When the mercury in the thermometers stabilizes, record the temperature. Remove the thermometers after each reading.

Continue to check and record the temperatures throughout the day. Compile a log of times and temperatures, and then graph the data. You might run this experiment for a single class period, for one day, for a season, or for an entire school year.

The carton facing the outside will show temperature readings significantly higher than will the inward-facing carton. As well, the soil from the simulated south-facing slope will retain heat longer.

Discuss the results with your class. What was the greatest difference in temperature between the two cartons? What was the least difference? When did those readings occur? Was there a difference in how quickly the soil samples heated up or cooled down between readings? How does slope aspect affect soil temperature? How might your conclusions apply to the people of the Hupobi and their dry-farming techniques? (The ancient inhabitants of the Hupobi planted those crops requiring higher temperatures and a longer growing season (such as maize) on south-facing slopes. Crops that grow for a shorter period and in cooler temperatures (such as squash) were planted on the other slopes.)



These lessons were developed by Terrill L. Nickerson, the Santa Fe Indian School.

U.S. DEPARTMENT OF THE INTERIOR
MARCH 3, 1849

EXPLORING ANCI

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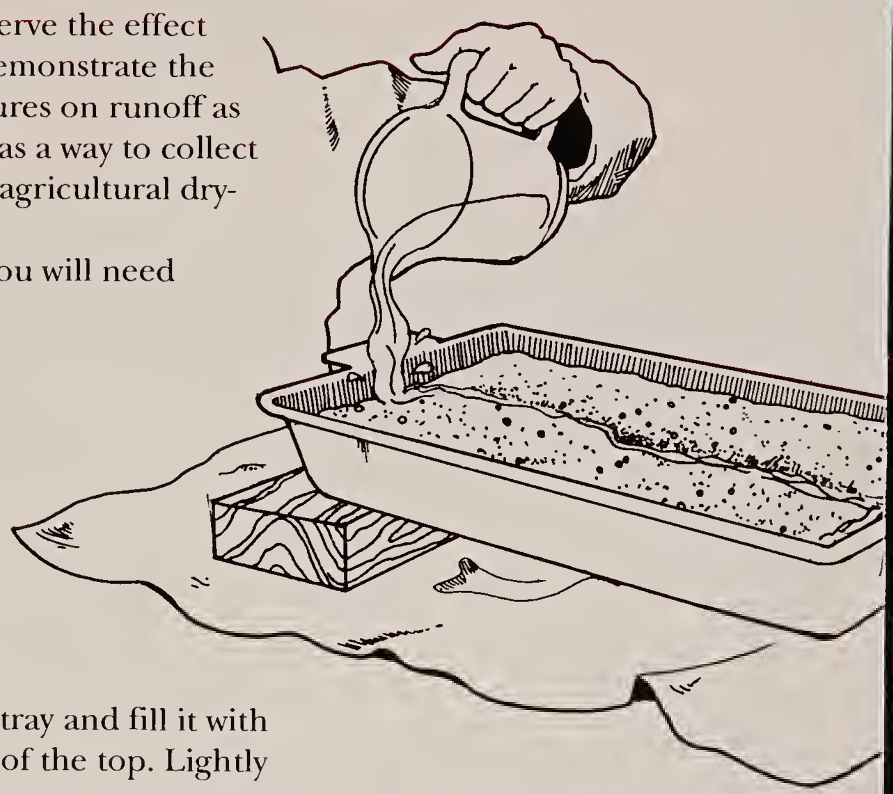
WATER DIVERSION



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Materials: For this activity, you will need

- ✱ a large plastic tray (such as a kitty litter box);
- ✱ soil and gravel;
- ✱ a wooden block to support the tray;
- ✱ water;
- ✱ pebbles, small stones, or popsicle sticks;
- ✱ a 500-ml beaker;
- ✱ and a plastic drop cloth.

Procedure: Take the plastic tray and fill it with soil to within one centimeter of the top. Lightly pack the soil.

Pour about 500 ml water into the beaker, then place the tray on top of the plastic drop cloth. Tilt the tray about 20 degrees, supporting it on the wooden block. Gently pour the water from the beaker onto the middle area of the soil. Do not let the water flow too rapidly. Observe the pattern that the water makes as it runs down through the soil.

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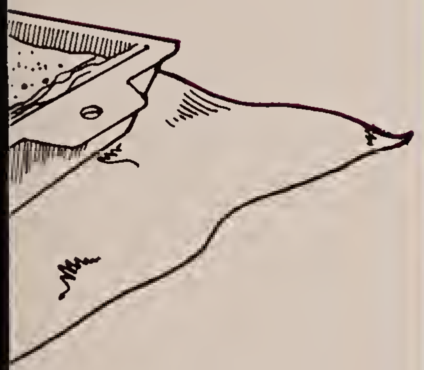

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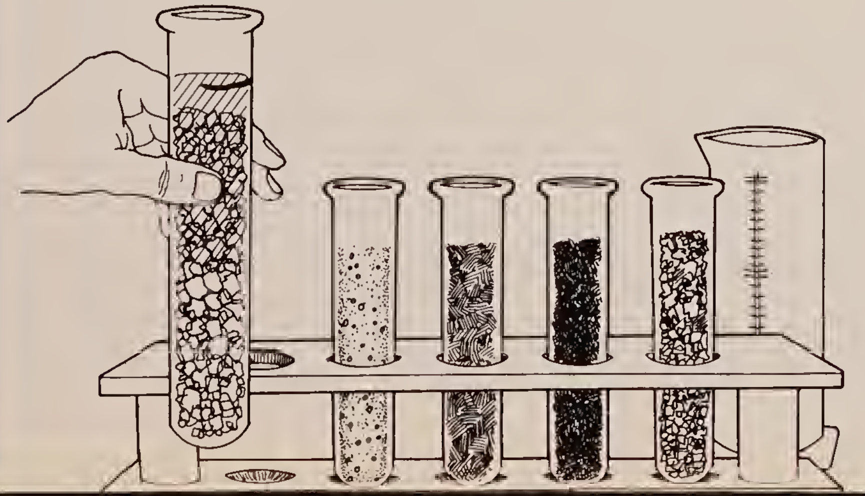

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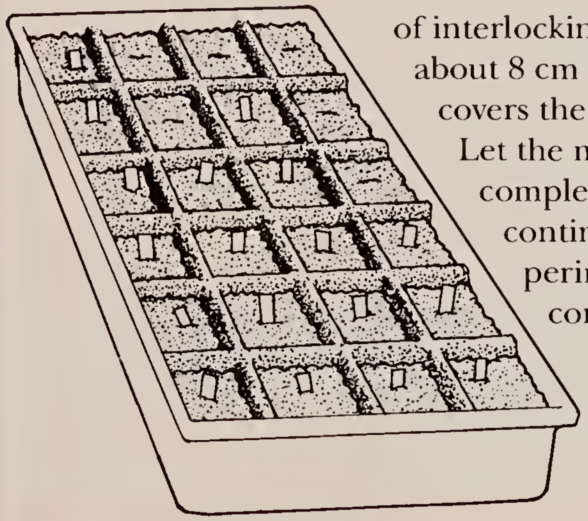

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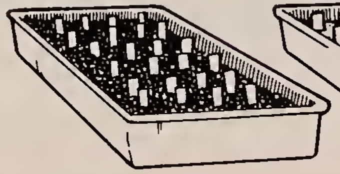

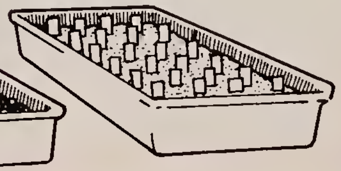

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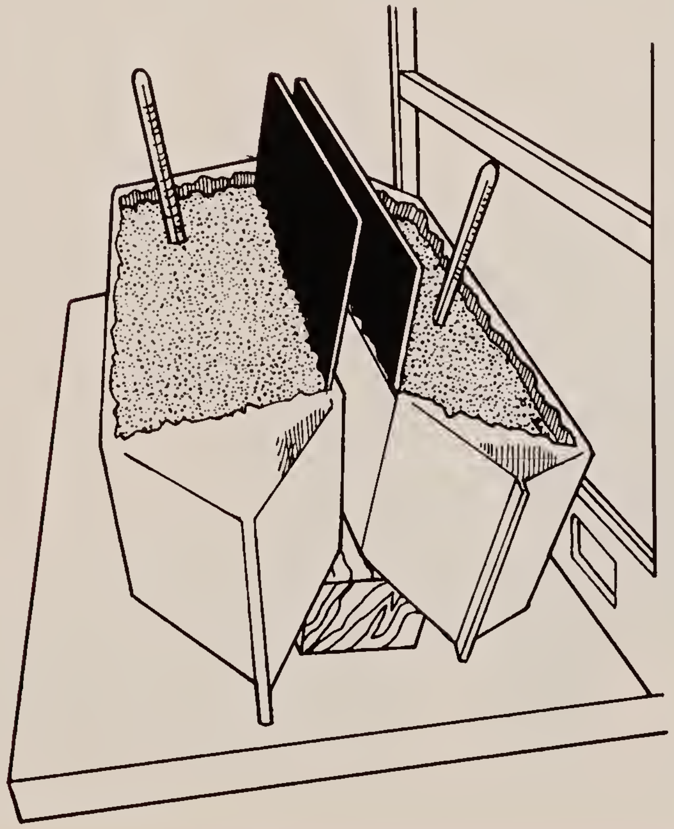

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